XXII. *On the mechanism of the Spine.* By HENRY EARLE, *Esq. F. R. S. Surgeon to the Foundling, and Assistant Surgeon to St. Bartholomew's Hospital.*

Read April 25, 1822.

HAVING been lately engaged in examining the structure of the vertebræ in different animals, I have been particularly struck with the mechanism of the spine and spinal canal in birds, by which a most remarkable degree of motion is gained in the neck, without any injury or pressure on a part of such vital importance to the existence of animal life, as the spinal marrow; an extent of motion, so great indeed as completely to compensate for the deficiency of it in the dorsal and lumbar regions, as well as for the want of any prehensile power in the anterior extremities. In attempting to explain the nature of this peculiar mechanism, which tends to throw considerable light on the physiology and pathology of the spine, I believe that I have not been preceded by any author. The cervical vertebræ in birds are very numerous, varying from nine to twenty-four.* They differ considerably from one another, according to their situation, in the form and direction of their articulating surfaces, and in the number and shape of

* This great diversity in the number of the cervical vertebræ in birds, is the more remarkable, when contrasted with the uniformity which pervades the class mammalia, where the number (with one single exception, the three-toed sloth) is constantly seven. The mole, whose head appears lost between the scapulæ, has precisely the same number as the giraffe and the horse.

the different processes, which afford extensive means of attachment to the muscles concerned in the different motions of the neck. Unlike the vertebræ in man and most of the mammalia, they are articulated together by complicated joints, which bear a close resemblance to the articulation of the olecranon with the humerus in the human subject, but differing in some respects; the vertebræ in birds admitting of lateral motion as well as flexion and extension, whilst the elbow is strictly a hinge-like joint.

The varying position of these articular surfaces is greatly favoured by the interposition of a cartilage, which is curiously adapted to the surface of each bone, and is enclosed between reduplications of synovial membrane; and thus each joint is double, consisting of two synovial cavities, and is analogous to the articulation of the lower jaw in man; a circumstance, I believe, not mentioned either by CUVIER, BLUMENBACH, or MACARTNEY.

The canal of each vertebra is of very unequal calibre, the centre being narrowest. It enlarges above and below, and at each joint is nearly three times the capacity that it is in the centre; and thus the canal of each individual vertebra may not unaptly be compared to an hour-glass. The canal is closed in front by the posterior surfaces of the bodies of the vertebræ, but behind it is very imperfect; and in the skeleton there is a large lozenge-shaped opening, formed by the diverging inferior articular processes and the converging plates which unite to form the back of the canal. This, in a recent state, is filled up by a membrane, and is protected by the highly elastic and powerful ligamentum nuchæ.

This mechanism, besides allowing of the greatest possible

freedom of motion, appears to be intended, at the same time, to guard against the possibility of any undue pressure on the spinal marrow. This is very readily demonstrated by removing the ligamentum nuchæ and membrane which closes the above mentioned opening. The spinal marrow, enveloped in its membranes, will immediately come in view. Its outer membrane is very vascular, and of a delicate structure, and is connected with the canal by a fine filamentous cellular substance; it is larger than the inner membrane, with which it is but loosely connected.

When the spinal canal has been thus exposed, the individual vertebræ may be bent backward to a right angle, and laterally to an angle of 45°, without in the least compressing the marrow which occupies so small a space of the whole calibre of the canal at each articulation, as to be quite secured from any injury from this motion. The design, in this structure, becomes even yet more obvious, on viewing the whole extent of the spinal cord. It is nearly of the same size throughout, diminishing very gradually from above downwards, and completely occupies the narrow central part of the canal of each cervical vertebra, where no motion can affect it. The same may be observed in that part of the spine which corresponds to the dorsal and lumbar divisions, which in birds do not admit of motion; for here we find no variation, either in the spinal canal or the marrow, except where the numerous branches are given off to form the great sciatic plexus, to supply the lower extremities, where it swells out into a bulbous shape, corresponding to the cavity in the bone.

Before quitting the subject of the spine in birds, it will be

right to mention one more peculiarity, apparently connected with the same mechanism. Contrary to the usual course in other animals, the nerves that are given off from the cervical portion of the spinal marrow, pass obliquely upwards at a considerable angle, through an opening between the root of the inferior articulating process, and the body of the bone; they then divide, and one branch descends through the opening in the lateral process, and the other branch is distributed to the surrounding muscles and integuments.

One principal object in comparative anatomy, or rather in comparative physiology, is to enable us, by examining particular structures, which are more developed in some animals, and in whom consequently the functions of such structures are more apparent, to judge of the probable uses of similar structures existing in a diminished proportion in other animals. On investigating this subject, and examining the spines of several other animals, I have found a similar arrangement, varying only in degree, and that exactly in proportion to the extent of motion permitted between the vertebræ.*

In the formation of the spine in man, it was requisite to combine two very opposite qualities. The solidity and strength of a column were required to be united with the flexibility necessary to the performance of our diversified actions. To attain

* This rule will be found to hold good, even in those animals which form exceptions, with respect to the general form and arrangement of the different processes. Thus, in the mole, whose cervical vertebræ are mere bony rings without any spinous processes, and which, consequently, admit of extensive motion, the canal is remarkably capacious. In the bat, whose dorsal vertebræ are either wholly without spinous processes, or have only short tubercles, the canal, at this part, is of greater volume than either in the cervical or lumbar vertebræ; and, contrary to the general rule, this division of the spine admits of considerable motion.

these various ends, this beautiful structure is admirably adapted. The broad horizontal planes afforded by the bodies of the vertebræ, the mechanical locking of the articular processes, and the powerful ligamentous bands which unite them, so connect the whole as to form one column, whilst the numerous articulations into which it is subdivided, which are separated by masses of highly elastic matter, at once interrupt the effect of concussion, and allow a slight extent of yielding of one vertebra upon the other. The motions of the individual vertebra are obscure and limited, but the aggregate of the whole is considerable. The extent of motion varies in each region; in the back, every thing conspires to limit it; but in the neck and loins it is much greater; and in sawing open the spinal canal, we find a very similar provision to that which I have before described in birds, namely, an exact correspondence between the extent of motion permitted, and the size and form of the canal. Thus, in the dorsal division, where motion hardly exists, its calibre is less; it is of a rounded form, and it is more closely adapted to the size of its contents. In the superior cervical vertebræ, where the extent of motion is greater, the canal is of a triangular form, and is considerably larger in proportion to the spinal cord. In the lumbar vertebræ it is also triangular, and much more capacious than in the dorsal. Obviously, with the same intention, the theca is very loosely connected with the bony canal, and a considerable space is left between it and the other membranes, to allow of a sufficient play of one surface on the other, so that at the greatest extent of natural curve, no perceptible stretching of the marrow can take place, which would be liable to continual pressure, if, closely enveloped in its

membranes, it completely filled the canal, in every motion of which it must, in that case, participate.

To afford additional support to the marrow which this loose state of membranes would leave very insecure, if enclosed in so delicate a tissue as the pia mater of the brain, this membrane, which may be considered as the proper tunic of the marrow, is greatly thickened, and partakes more of the characters of a fibrous membrane.

The membranous band, which has been termed the ligamentum denticulatum, appears to be superadded to restrain the lateral motions of the marrow, and to steady it in the canal. By these membranous processes, the marrow may not, improperly, be said to be lashed to the sides of the spinal sheath, in which, from the disproportion between them, it would otherwise be liable to perpetual variation of position, and pressure from the bony parietes. That a certain degree of freedom of motion between the membranes is essential to the due performance of the functions of the spinal marrow, is proved by the effect of accidents and disease. It would be out of place here, to bring forward a detail of particular cases, but I may mention briefly, that I have ascertained, by dissection, that the most distressing train of nervous symptoms, and even complete paraplegia, may be produced by adhesions taking place between the membranes, and by effusion into the canal or theca.

In conclusion I may observe, that this view of the subject tends to throw considerable light on the pathology of the spine, and assists in explaining a circumstance which I have repeatedly noticed in diseases affecting the vertebræ, namely, that the symptoms of irritation and inflammation of the spinal

marrow, are much more early manifested, and are generally far more serious in their consequences when the dorsal vertebræ are affected, than when either the cervical or lumbar are the seat of disease. In the former case, the slightest congestion or effusion is often productive of serious symptoms, from the canal being smaller and more completely filled with the marrow and its membranes; whilst, in the latter description of cases, from the greater capacity of the canal and looseness of the membranes, considerable effusion may exist, without, at first, producing any marked symptoms, more particularly in the lumbar region, where other circumstances concur in rendering the effect of pressure less sensibly felt; to enter into a description of which, would be foreign to the object of this paper.

As it is difficult to convey any clear idea of complicated forms by words, I have subjoined a sketch of some cervical vertebræ in birds, with a description of the different parts.

EXPLANATION OF PLATE XXX.

Figure 1. Represents an anterior view of a single cervical vertebra.

Fig. 2. A posterior view of the same.

Fig. 3. A lateral view of the same.

Fig. 4. A front view of two vertebræ articulated together.

Fig. 5. A back view of the same.

The letters of reference are the same in all the figures.

A. The body of the vertebra.

BB. lateral processes.

CC. Styloid processes, with tubercles near their base, which restrain the motion of the vertebræ in the anterior direction.

Fig. 1.

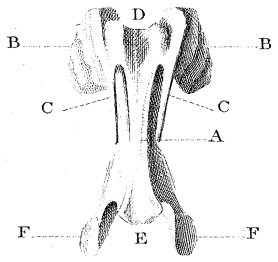


Fig. 2.

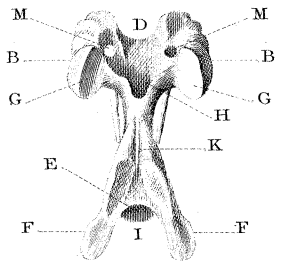


Fig. 3.

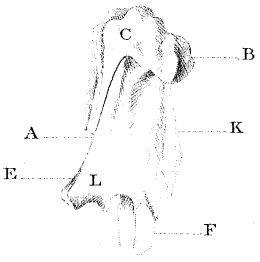


Fig. 4.

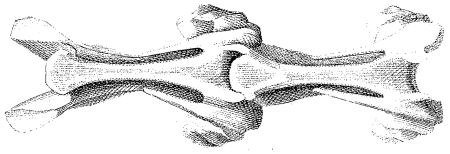


Fig. 5

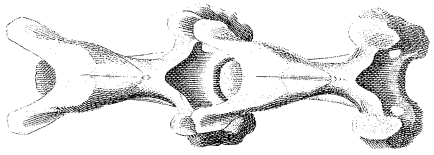
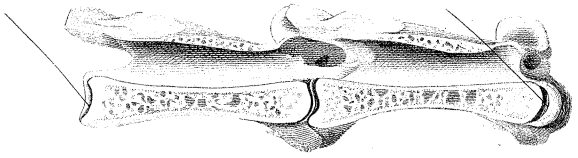


Fig. 6.



In some birds, at the upper part of the neck, a bony arch extends from one to the other, to preserve the blood vessels which pass under it from pressure. This is the case in the heron, and other very voracious birds.

D. Lunated excavation for articulation with the superior vertebra.

E. Semi-lunar convexity, corresponding to the excavation above mentioned.

F F. Diverging inferior articular processes, with surfaces facing obliquely outward.

G G. Superior articular surfaces, facing obliquely inwards.

H. I. Spinal canal, imperfect in the skeleton, in consequence of the vacancy left between the diverging inferior articular processes and the superior converging plates, which unite to form the back of the canal K.

L. Opening for the passage of the spinal nerves.

M. Foramen for the passage of the carotid artery and branches of the spinal nerves.

Fig. 6. A perpendicular section of two vertebræ, showing the interarticular cartilages.

28, George Street, Hanover Square,
April 2, 1822.